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ABSTRACT

This study investigated the feasibility of using the ordering theoretic procedure with multiple choice items, and its usefulness as an interpretive aid for intelligence test data. Data from two components of a group-administered multiple choice intelligence test (Otis-Lennon Mental Ability Tests) were analyzed using ordering theory procedure for locating prerequisite relations among items. The results supported the applicability of the procedure to multiple choice items. Specifically, the method produced results for the verbal omnibus subtest which were replicated in large part with a second, quite different, sample. The Figural Series Completion subtest was analyzed for only one sample. In both subtests, the shapes of the hierarchies reflected the relative homogeneity or heterogeneity of the two scales and the relationships appeared to be logically valid. However, particularly in the case of the verbal subtest, results were highly item specific and of limited generalizability unless used in conjunction with theories of cognition. Nevertheless, the ordering theoretic analysis produced information and insights which would not have emerged with more conventional analyses. (Author/RD)

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On the Use of Ordering Theory with Intelligence Test Items

Janice Scheuneman

The Psychological Corporation

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On the Use of Ordering Theory with Intelligence Test Items

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In the present climate of public hostility toward standardized tests in general and toward intelligence tests in particular, test scores would be more defensible if they could be accompanied by some kind of statement concerning what kinds of tasks can be performed by persons with a given range of scores. Such an interpretation would be very much aided by knowledge of hierarchical relationships which may exist among the items, such that success on some test items could be inferred from success or failure on other items. Understanding of the skills necessary for solution of an item would also be enhanced by examining those items which appear to stand in a prerequisite relationship to the item in question. Such an analysis of intelligence test items would therefore provide information concerning what kinds of skills are being measured by these tests.

The ordering theoretic method, introduced by Bart and Krus (1973), is designed to identify such item hierarchies where they exist. This procedure does not assume linear hierarchies, where all items are ordered along a single continuum with each preceding the next. Instead, the procedure permits the construction of branched hierarchies, with several paths interrelating different items. However, while a certain allowance is built into the system for exceptional cases, or careless responding, it was not designed to allow for the operation of chance as in multiple-choice tests.

The purposes of this study were two-fold. Basically this was an exploratory study designed first to determine if the method could be used with multiple-choice items and second to study the kinds of results which could be obtained with different samples and different tests.

Procedure

The ordering theoretic method requires dichotomous scoring of 0 and 1 for each item. In order to infer that a prerequisite relationship exists between a pair of items, the responses to those items are examined. If item A precedes item B, the response patterns 1-1 (both items correct), 0-0 (both item incorrect), and 1-0 (A correct and B incorrect) would be expected to occur, but the pattern 0-1 (A incorrect and B correct) should not occur. Hence this pattern is referred to as a disconfirming case. The basis for analysis of the data into hierarchies is a matrix of the number of disconfirming cases for all possible pairs of items. Notice that since the number of correct and incorrect responses for each item is also known, once the number of disconfirming cases has been established for any given pair of items, the other four patterns can easily be generated if desired, as in any contingency table. These totals for each item, the number of correct and incorrect responses will be referred to as the marginals in the discussion that follows.

While the number of disconfirming cases should be zero if A precedes B, in practice this will rarely be the case and some tolerance of five or ten percent disconfirming cases is usually accepted. However, several of the items investigated in this study had extreme difficulty values (either very easy or very difficult), and use of a flat five percent tolerance level with these items produced some anomalous results. If item A precedes item B, two conclusions follow: (a) If item B is correct, item A is correct, and (b) if item A is not correct, item B is not correct. Use of a flat tolerance rate will sometimes suggest that a precedence relationship exists when just one of these conclusions is true. For example, Figure 1 shows three pairings of hypothetical items A, B, C, and D. In all three examples, 100

cases are assumed, so that the five disconfirming cases in each are accepted at the five percent tolerance level in concluding that a precedence relationship exists. In Example 1, A is presumed to precede B, but in fact when item B is correct, item A is never correct so the precedence relationship as defined above does not exist. In Example 2, Item D would be presumed to precede item C. However, in those cases where item D is not correct, item C is not correct only 50 percent of the time. This is probably more tolerance than we really wish to allow. Only in Example 3, where item A appears to precede item C, do the results support the conclusion of precedence. Therefore, an alternate method of assigning tolerance levels to a pair of items was developed.

When item A precedes item B, it is by logical necessity easier than item B, from which it can be determined that the number of disconfirming cases can not be larger than the smallest of the four marginal totals for that pair of items. Therefore, rather than setting the tolerance level as a percentage of the total number of observations, tolerance was set at 25 percent of the smallest marginal. Use of this rule resulted in levels which were frequently less than five percent of the total, and which theoretically could produce a tolerance level as high as 12.5 percent (one quarter of 50 percent, the highest possible smallest marginal). In this study, no precedence relationships were found that exceeded 10 percent of the total. In addition, the kind of anomalous results demonstrated in Figure 1 were thus avoided. With a rule of 25 percent of the smallest marginal, both conclusions are true at least 75 percent of the time.

The data were collected as part of two special studies using the item analysis edition of the 1979 revision of the Otis-Lennon Mental Ability Tests. The first sample was tested in the fall of 1976 in a rural southern school

district with approximately 90 percent Black enrollment. The second sample was tested in the winter of 1977, and was made up of children from three communities in New York state, selected to cover a range of socioeconomic levels. These were (a) an urban community with about 15 percent minority enrollment, (b) a well-to-do suburb of New York City, and (c) an upstate rural community. All children tested were enrolled in the second grade.

The two tests selected for analysis were chosen because they were quite different in content and in the homogeneity of the items. The first test studied was a verbal omnibus test dictated by the teacher, which tested aspects of listening comprehension, ability to follow directions, and quantitative reasoning. This test consisted of 30 four-option multiple-choice items. The second test was a figural series completion test which pupils worked at their own pace without time limit. Stimuli included simple pictures, geometric configurations, and letters or numbers. The test contained 20 five-option multiple-choice items.

Results

The Verbal Test

The verbal omnibus test was analysed for hierarchical relationships among the items, separately for the southern sample and the New York state sample. However, preliminary analysis of the data for the New York state sample indicated relatively few such relationships. The difficulty appeared to be due to the large proportion of children in that sample who got most of the items correct. In such a case, the relationships among the items are masked because difficulty values (proportion correct) are high and differences between them are small. Hence, cases were selected who had low scores on a subset of the items. The resultant sample was then reanalyzed for hierarchical relationships. The item data for the two samples are given in Table 1.

Comparison of item difficulty values shows the two samples to be fairly equivalent, except on a few items which will be discussed later.

The matrices of disconfirming cases for the two samples are given in Tables 2 and 3. (Items 3, 18, 22, and 26 were dropped because they had no more than one relationship in either sample.) Using the tolerance level discussed above, 90 pairs of items showed precedent relationships in the southern sample and 80 relationships appeared in the New York state sample. Of these, 54 relationships were found in both samples. For a thirty item test, there are 435 possible relationships of which 66 could not occur with both samples because of shifts in rank order of item difficulty. Of the 369 confirmable relationships then, where 80 and 90 relationships respectively were found with each sample, approximately 18 relationships would have been expected to agree by chance. Therefore, the 54 relationships which were obtained from both samples appear to reflect interrelationships of the items rather than peculiarities of the individual samples. These relationships are given in Table 4.

The hierarchies obtained in this test are largely horizontal. That is, although many items show relationships with several other items, only item 4, in which the child is asked to find a quantity less than a given quantity, is both preceded and followed by other items. Item 6, which asks the child to mark the third car in a row of four, precedes 15 other items in the test. Item 13, which presents a circle divided into six equal segments and asks the child how many segments are in half the circle, is preceded by eight other items. Figures 2, 3, and 4 give the hierarchies found among the items. These were divided somewhat arbitrarily into three parts in order to make the relationships more easily visible. Except that Figure 4 contains most of the items intended to measure quantitative

concepts, there does not seem to be a meaningful distinction among the three sets. However, examining the content of the items shows that the relationships shown are generally reasonable and to be expected. (The items appearing in the hierarchies are described in Appendix A.) It is interesting for example to note the three part relationship of the ordinal number concept of item 6, preceding the "less than" concept of item 4, preceding the concept of one half in item 13. Item 7 where the child must mark the lines that are both pointing down, precedes item 28 where they must mark the lines that are going in different directions. Items 15 and 30 provide an interesting contrast. Both require four objects to be arranged in order of size and both are of roughly equal difficulty. However, item 15, which is fairly straight forward, is preceded by items 6 and 7, ordinal numbers and different length lines; while item 30, which is rather complex, is preceded by two listening comprehension items.

In looking to see where the results from the two hierarchies do not agree, most relationships which were not confirmed concerned items with extreme difficulty values, primarily items 1, 5, and 7 which were very easy and item 19 which was very difficult. With these items, very few disconfirming cases were possible and precedence relationships often involved only one or two people. It is probably not surprising that these should be somewhat unstable. Another apparent source of discrepancy is that the relationships found are partially a function of the distance between two items; that is, to a certain extent, the greater the difference in difficulty between two items, the more likely that a precedence relationship will be found. Therefore, a large change in the relative difficulty of an item from one sample to another will probably change the relationship of that item with others in the test. Referring again to Table 1, the items with

the largest differences in difficulty between samples are items 4, 8, 17, and 23. Together, these four items showed 15 relationships in the southern sample which were not confirmed in the other sample. (As as aside, it is interesting to note that all four of these items showed evidence of ethnic group bias in an independent study conducted with first graders, and items 4 and 17 were also biased when tested at third grade.) For the New York sample, only item 4 was both preceded and followed by other items. In the southern sample, seven items had both kinds of relationships, although three of these, 6, 7, and 20, were preceded only by item 1. The other items which were botn preceded and followed by other items were items 4, 12, 17, and 29. Two items had precedence relations with only one sample, item 11 with the southern and item 2 with the New York sample.

The results from the hierarchies can also be compared with the standard item indices given in Table 1. There does appear to be some agreement between the typical discrimination index, in this case the biserial correlation, and position in the hierarchy. Although having a weak relationship with other items on the test as indicated by the biserial does not appear to preclude the presence of that item in the hierarchy, the six items which had no confirmed relationships all had quite low biserials for at least one of the samples. Also, except for the very difficult items 19 and 27, the two poorest items were 15 and 30 which had only two precedence relationships each. The more difficult items are harder to interpret since, for some of the reasons discussed above, they are more likely to show precedence relationships. It is interesting to note however, that when only the high scoring New York sample was analyzed, although all three of the hardest items remained relatively difficult, only item 9 continued to show precedence relationships. Since this item was included in the subscale which

was used to divide the New York sample into groups, it is possible that the biserial for this item is underestimated. However, except for very easy or very difficult items, it seems reasonable to conclude that poor items, as indicated by low biserial correlations, will not fit well into a hierarchy.

The Figure Series Completion Test

In this test the distribution was highly skewed with many perfect and near perfect scores in both samples. Again, so the hierarchy could emerge, all cases with scores of 17 or higher on the twenty item test were discarded. Although this left only 55 cases in the New York sample and 53 in the southern sample, the analyses were performed separately for the two groups. However, evidence from other studies using this test suggested that it was not comparable in various ways for Blacks and Whites. (It was eventually dropped from consideration for the final version of the new Otis-Lennon for this and other reasons.) This finding of noncomparability between Blacks and Whites was supported in the hierarchical data. Relatively few relationships were found among the items for the southern sample. This may be due, at least in part, to the instructions being inadequate for this group. Examination of the response patterns for several of the southern children suggested that they did not understand what they were supposed to be doing until well into the test. Hence, these data were not analyzed further.

For the New York sample, however, the data were surprisingly regular, particularly when compared to the verbal test data. The item statistics are presented in Table 5 and the matrix of disconfirming cases is given in Table 6. The resulting hierarchy is given in Figure 5. The hierarchy shows two items, 1 and 2, preceding all the others. These two items both test a

series which is a simple alternation of two figures. (See Appendix B for a description of the items in the hierarchy). Other relationships shown also appear to be meaningful. Item 19, for example, is a series of three very similar configurations of small circles and lines. It is preceded by item 8, which is an alternating series of 3 letters, and item 15, which uses three punctuation marks. Item 9 involves a series of four which is made up of two shapes in two colors. It is preceded by item 13, a series of four made up of two pairs of letter-like shapes, and by items 11 and 12, which were both a series of 4 distinctly different objects. Item 18 is the most complex item which entered the hierarchy. It involves three sets of three different shapes in which the relationship in each set is the same (reverse the figure, then reverse it back to its original form). It is not surprising that in order to accomplish this item, a child must be able to handle many of the others. This item is preceded by eight other items.

It is interesting to contrast the hierarchy in Figure 5 with those obtained with the verbal test. Unlike those hierarchies, the series completion hierarchy is largely vertical showing a number of levels. Three paths show four items each--Items 1, 10, 5, and 7 or 18 and items 1, 8, 19, and 18. The difference seems to be a result of the greater homogeneity of the series scale. It is likely that a number of different items measuring quite similar tasks are necessary to produce this kind of result. In addition, unlike the verbal test, none of the items appeared to be particularly poor. Those which did not fit into the hierarchy showed variations which were unlike others in the test. For example, item 16 was a series of four dissimilar objects, but required the child to fill in an element missing from the middle of the series rather than the end. In general it would appear that the kind of information yielded by this analysis would be useful in the construction of a test using this type of item.

Conclusions

The major purposes of the study were to investigate the feasibility of using the ordering theoretic procedure with multiple-choice items and to study it as an interpretive aid for the intelligence test data. The results of this study support the applicability of the procedure to multiple-choice items. The procedure produced results for the verbal test which were replicated in large part with a second quite different sample. In both tests, the shapes of the hierarchies reflected the relative homogeneity or heterogeneity of the two scales and the relationships found appeared to be logically valid.

Following this study, certain recommendations can also be made for further studies, either with multiple-choice or open-ended items measuring ability or achievement. First, the sample of people used to study the items should probably not be too heterogeneous. In particular, persons with very high or very low scores mask precedence relationships because there is little distinction between items when most are either correct or incorrect. Ideally, most subjects should get about half the items correct. On the other hand, the items should represent a range of difficulty. Since it is unlikely that an item will precede another of similar difficulty, a test made up of items with a small range of difficulty values would probably not yield interesting results with the ordering theoretic procedure.

The results are less clear with regard to interpretation of the test. The interrelationships among the items tell a great deal about the kinds of skills the items are measuring, as well as providing some insight concerning the development of those skills. However, particularly in the case of the verbal test, the results are so complex and so tied to specific items that a great deal of further research will be required before generalizable conclusions can be obtained. At some point in the future it may be

possible to develop the theoretical and empirical base required to produce a test using ordering theoretic analysis as part of the construction process. Such a test might then lend itself to the type of interpretation envisioned at the beginning of the paper.

If the goal of such an analysis is to tell test constructors what kinds of things they are building into group intelligence measures, however, the ordering theoretic procedure produces information and insights which might not be available from more conventional means of analysis. The results are rich in data which may produce hypotheses for further investigation under other research designs.

References

Bart, W. M. & Krus, D. J. An ordering-theoretic method to determine hierarchies among items. Educational and Psychological Measurement, 1973, 33, 291-300.

Guilford, J. P. Psychometric Methods. New York: McGraw-Hill, 1954.

Table 1

Item Statistics - Verbal Test

Item No.	Southern Sample		New York Sample	
	p[a]	bis[b]	p[a]	bis[b]
1	94	.53	96	.42
2	50	.12	60	.62
3	23	-.10	14	-.07
4	43	.70	86	.48
5	85	.48	93	.45
6	87	.56	94	.57
7	88	.50	96	.50
8	23	.56	60	.63
9	12	.50	17	-.13
10	20	.38	31	.40
11	49	.24	55	.27
12	47	.58	60	.30
13	20	.48	29	.46
14	75	.45	90	.00
15	27	.04	31	.00
16	78	.60	87	.50
17	44	.68	66	.50
18	31	.08	25	.40
19	19	.10	15	.15
20	74	.69	75	.27
21	47	.64	50	.60
22	36	.11	23	.09
23	33	.60	53	.22
24	43	.46	31	.29
25	37	.60	35	.37
26	57	.19	43	.25
27	16	.20	27	.00
28	31	.24	32	.36
29	44	.48	45	.59
30	31	.09	30	.02
	N = 108		N = 96	

[a]percent responding correctly to the item

[b]biserial correlation of item with total score using performance of top and bottom 27% and obtained from an abac. (Guilford, 1954.)

Table 2

Disconfirming Cases - Verbal Test
Southern Rural District[a]
(N = 108)

Items	1	7	6	5	16	14	20	2	11	12	21	17	29	4	24	25	23	28	30	15	8	10	13	19	27	9	No. incorrect
1	-	2*	2*	4	3	2*	2*	4	5	1*	2*	2*	3	2*	4	1*	1*	1*	1*	3	1*	1*	1*	2*	0*	1*	7
7		-	6	10	7	6	8	6	6	5	2*	4	6	3*	6	2*	1*	4	3*	3*	2*	3*	1*	3*	0*	3*	13
6			-	11	9	7	7	10	7	4	2*	3*	2*	3*	4	2*	2*	3*	5	5	1*	3*	2*	4	4	2*	14
5				-	12	13	12	7	7	6	10	6	6	9	9	4*	3*	4*	6	5	2*	4*	1*	2*	2*	1*	16
16					-	17	16	11	9	10	7	6*	10	5*	7	4*	5*	5*	8	9	2*	4*	3*	4*	2*	3*	24
14						-	14	14	15	11	10	10	10	8	6*	7*	8	8	6*	8	5*	5*	3*	8	5	5	27
20							-	10	14	6*	10	6*	7*	4*	6*	8	4*	6*	8	7*	7	3*	4*	7	5	3*	28
2								-	27	25	27	22	26	22	24	22	20	19	17	15	11	7	12	9	5	5	54
11									-	29	24	14	23	21	23	21	17	19	24	15	7	12	10	10	10	7	55
12										-	25	18	21	17	19	17	14	17	16	17	17	8	10	9	10	5	57
21											-	21	19	21	16	17	16	16	16	9	11	10	11	8	9	7	57
17												-	19	17	25	19	18	20	21	14	9	9	8	8	12	4	60
29													-	20	22	19	19	17	14	13	12	9	8	11	14	5	60
4														-	19	18	13	21	19	14	11	9	4*	14	9	4	62
24															-	21	25	18	20	15	14	12	11	13	10	9	62
25																-	21	22	19	20	10	16	8	11	11	6	68
23																	-	20	19	22	14	11	14	17	10	9	72
28																		-	20	23	10	18	15	12	12	9	74
30																			-	20	20	17	17	13	10	9	74
15																				-	16	18	15	11	10	8	79
8																					-	14	15	15	11	6	83
10																						-	14	15	15	9	86
13																							-	17	11	8	86
19																								-	12	11	88
27																									-	8	91
9																										-	95
No. correct	101	95	94	92	84	81	80	54	53	51	51	48	48	46	46	40	36	34	34	29	25	22	22	20	17	13	

[a] item given in the row is assumed to precede the item given in the column in cases marked with an *.

Table 3

Disconfirming Cases - Verbal Test
New York Districts[a]
(N = 96)

Items	1	7	6	5	14	16	4	20	17	2	8	12	11	23	21	29	25	28	10	15	24	30	13	27	9	19	No. Incorrect
1	-	4	4	3	4	3	4	3	3	2	3	3	1*	2	0*	1*	0*	0*	1*	2	1*	0*	1*	1*	1*	1*	4
7		-	2	2	2	3	2	1*	1*	0*	1*	1*	1*	2	0*	1*	2	1*	1*	0*	0*	2	1*	2	0*	0*	4
6			-	6	5	4	2	4	1*	2	1*	1*	2	2	1*	2	0*	1*	3	1*	2	2	0*	2	1*	0*	6
5				-	5	5	4	5	3	3	3	4	4	4	3	1*	4	0*	4	4	0*	2*	2*	1*	2*	0*	7
14					-	9	8	7	7	5	7	6	5	6	5	6	5	5	5	4	1*	3	3	1*	0*	2*	10
16						-	7	7	5	6	2*	6	7	5	4	2*	3*	5	2*	4	3*	6	2*	4	3*	2*	12
4							-	9	5	5	2*	6	6	3*	6	3*	7	3*	5	4	4	4	1*	3*	4	1*	13
20								-	15	12	12	14	13	13	13	7	5*	10	4*	8	6*	8	4*	12	1*	3*	24
17									-	14	16	19	14	14	16	13	13	8*	8	9	10	12	10	13	8	1*	32
2										-	21	26	24	14	19	16	13	9	12	13	11	11	9	10	6	3*	39
8											-	21	21	17	15	10*	11	15	8	15	9	11	12	13	7	6	39
12												-	21	21	17	15	12	10	12	15	10	12	8	12	6	5	39
11													-	20	22	21	16	11	12	17	13	15	12	14	10	6	43
23														-	20	17	19	19	14	19	14	19	14	12	8	8	45
21															-	18	15	11	12	14	13	16	12	15	9	7	48
29																-	19	16	12	18	14	17	13	16	13	10	53
25																	-	23	17	20	19	15	18	19	7	13	62
28																		-	22	21	18	17	16	19	9	8	65
10																			-	21	25	23	17	21	13	11	66
15																				-	24	22	20	18	12	10	66
24																					-	18	20	23	8	9	66
30																						-	21	20	12	9	67
13																							-	16	15	10	68
27																								-	14	10	70
9																									-	12	80
19																										-	82
No. correct	92	92	90	89	10	84	83	72	64	57	57	57	53	51	48	43	34	31	30	30	30	29	28	26	16	14	

[a]item given in the row is assumed to precede the item given in the column in cases marked with an *.

Table 4

Relationships among items which were obtained with both samples[a]

Verbal Test

Item Numbers

Item number	4	17	12	21	29	23	8	24	25	28	30	15	10	13	27	19	09
1				X					X	X	X		X	X	X	X	X
7		X		X			X			X		X	X	X		X	X
6	X	X	X	X	X	X	X	X	X	X		X		X	X	X	X
5										X				X	X	X	X
16							X	X	X				X	X		X	X
14								X			X			X	X	X	X
20					X			X	X					X			X
4														X			

[a]A relationship found with one sample was also considered comfirmed if it was within 1 case of meeting the tolerance level in the second sample.

Table 5

Item Statistics - Series Completion

New York Sample (N = 55)

Item No.	p[a]	bis[b]
1	91	43
2	85	35
3	95	57
4	65	42
5	73	49
6	71	57
7	40	41
8	84	61
9	42	49
10	84	52
11	75	49
12	78	54
13	64	47
14	53	40
15	73	56
16	65	44
17	62	45
18	25	22
19	53	56
20	45	46

[a]percent responding correctly to the item

[b]biserial correlation of item with total score using performance of top and bottom 27% and obtained from an abac. (Guilford, 1954.)

Table 6

Disconfirming Cases - Series Completion Test
New York Districts [a]
(N = 55)

Items	3	1	2	8	10	12	11	5	15	6	4	16	13	17	14	19	20	9	7	18	No. incorrect
3	-	1	2	1	2	1	2	1	1	1	1	1	2	2	1	1	1	2	0*	0*	3
1		-	2	1*	1*	1*	2	0*	1*	0*	0*	4	1*	1*	2	0*	2	2	0*	0*	5
2			-	4	6	4	2*	3	5	3	4	6	3	4	3	3	3	1*	1*	2*	8
8				-	4	4	4	3	5	4	2*	7	4	6	2*	2*	4	2*	2*	3	9
10					-	5	6	1*	5	6	5	5	6	6	5	4	3	2*	3	2*	9
12						-	5	6	5	6	7	5	4	6	5	5	5	3*	4	3*	12
11							-	7	10	9	8	8	5	9	4	4	6	1*	6	2*	14
5								-	10	10	6	9	9	8	5	5	6	7	4*	3*	15
15									-	9	9	7	8	6	7	4*	5	6	5	3*	15
6										-	8	14	9	10	11	7	5	7	5	5	16
4											-	16	11	13	10	8	11	8	6	6	19
16												-	11	8	14	11	9	7	8	5	19
13													-	10	8	8	9	5*	10	5	20
17														-	12	7	6	11	8	5	21
14															-	12	12	6*	9	4	26
19																-	8	11	10	3*	26
20																	-	18	13	5	30
9																		-	13	6	32
7																			-	8	33
18																				-	41
No. correct	52	50	47	46	46	43	41	40	40	39	36	36	35	34	29	29	25	23	22	14	

[a] item given in the row is assumed to precede the item given in the column in cases marked with an *.

Figure 1

Hypothetical Examples for Four Items

Example 1:

		Item A: 1	Item A: 0	
Item B	1	0	5	5
	0	40	25	95
		70	30	

Example 2:

		Item D: 1	Item D: 0	
Item C	1	25	5	30
	0	65	5	70
		90	10	

Example 3

		Item A: 1	Item A: 0	
Item C	1	25	5	30
	0	45	25	70
		70	30	

1 = Item is correct

0 = Item is incorrect

Figure 2

Hierarchy of Relationships - Verbal Test Items

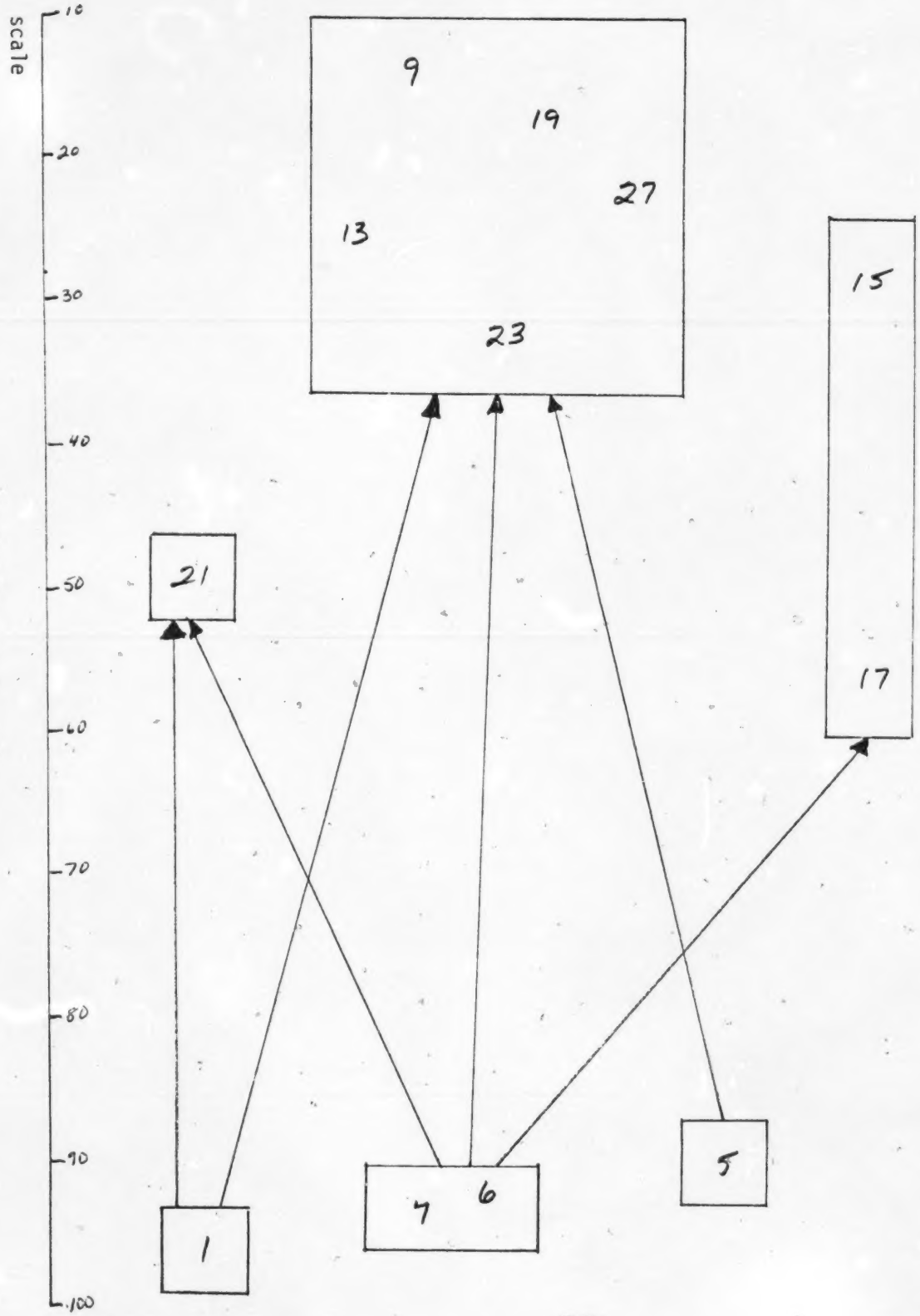


Figure 3

Hierarchy of Relationships - Verbal Test Items

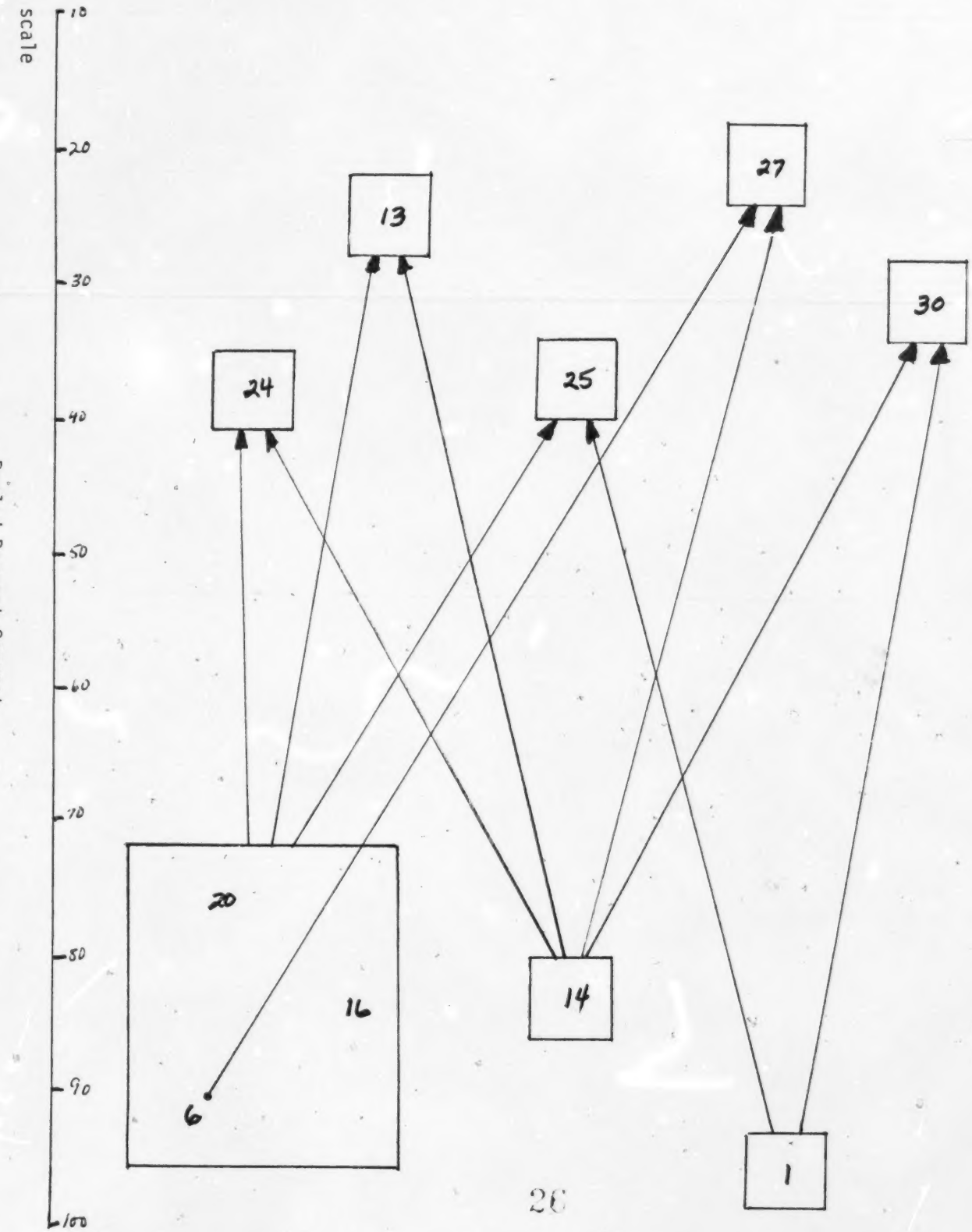


Figure 4

Hierarchy of Relationships - Verbal Test Items

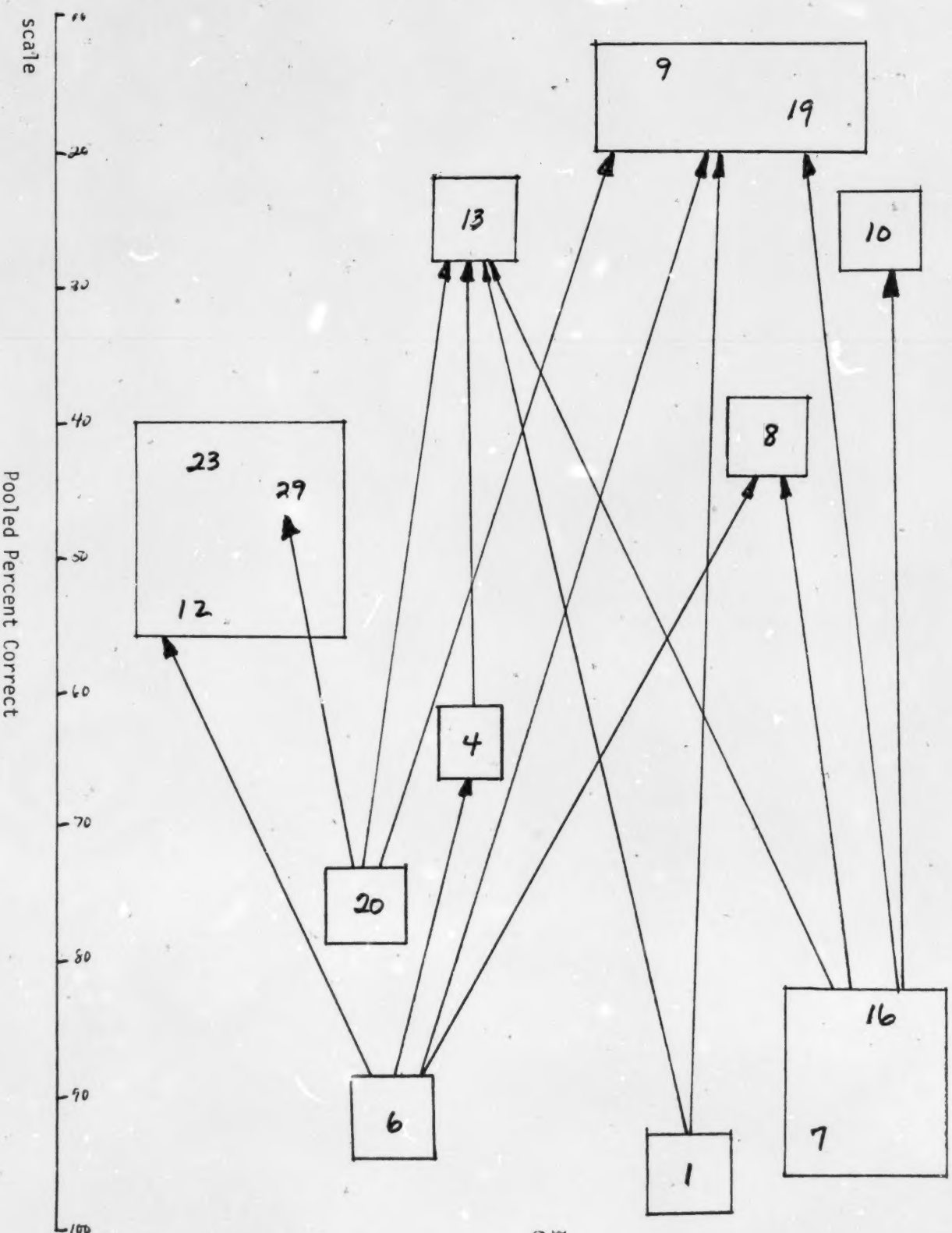
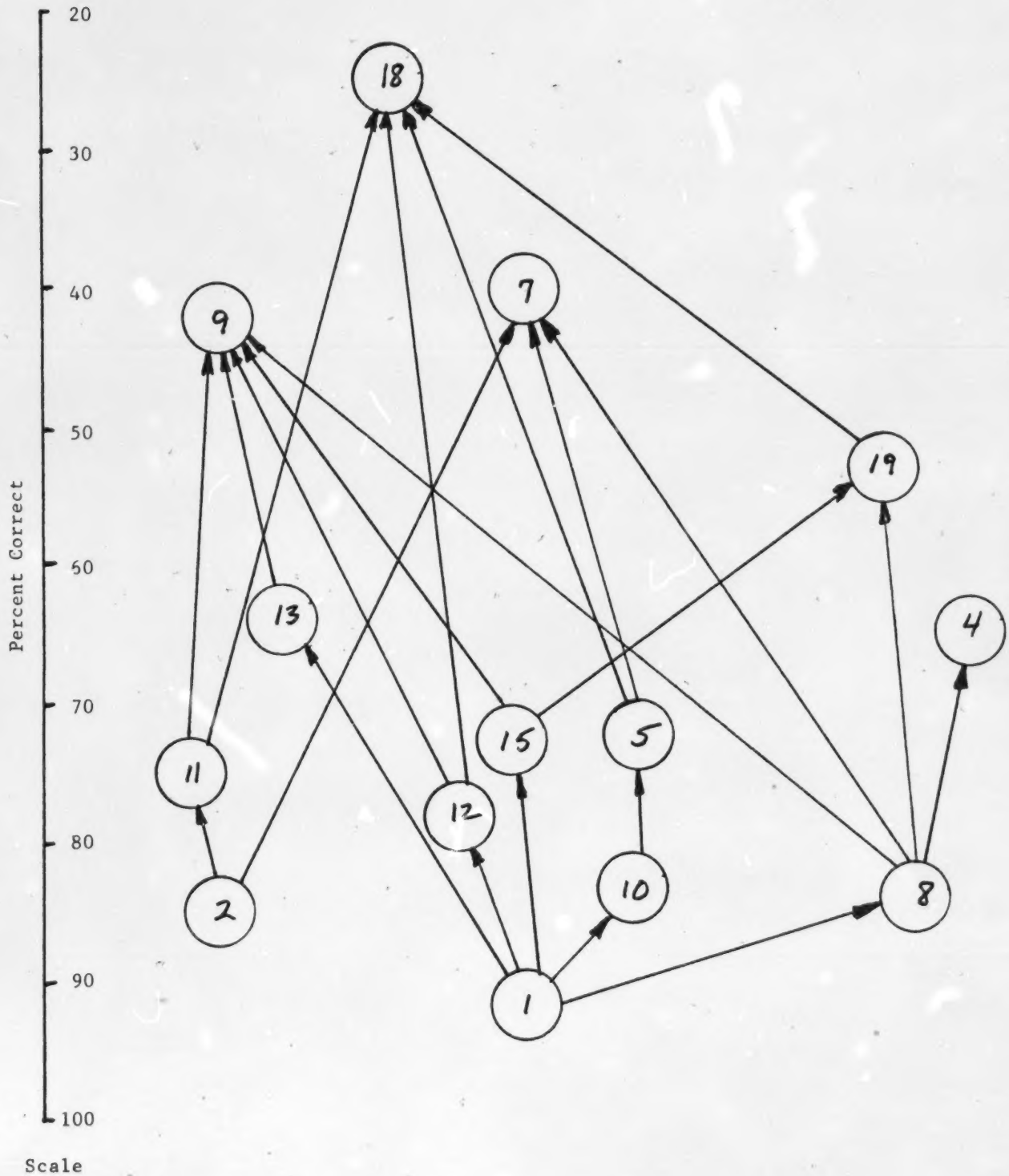


Figure 5

Hierarchical Relations - Series Completion Test



Appendix A

Verbal Test Items

(1) Jim did not catch the baseball when Chris threw it, and it broke something. Mark under the picture that shows what the ball broke. [Ans.: window]

(4) The box at the beginning of the row shows some bees. In the last part of the row, mark under the picture where the number of flowers is less than the number of bees. [There were 4 bees; Ans. is 3 flowers]

(5) You see a bucket of paint, a mop, a ladder, and a paint brush. Adam's mother is going to paint his room. Mark the picture that shows what she will not need to paint Adam's room.

(6) Mark the third car from the beginning of the row. [4 are pictured]

(7) Mark the picture that shows this: Both arrows point down and one is longer than the other.

(8) You see four children playing baseball. One player is not throwing the ball and is not trying to catch the ball. Mark under the picture of that player. [Ans.: girl ready to bat]

(9) Find the letter that is inside the next-to-largest circle and is farthest from the big X.

(10) The box at the beginning of the row shows just the right number of pretzels for Jamie and his friends to have two each. In the last part of the row, mark under the picture that shows Jamie and his friends. [8 pretzels arranged in 2 columns]

(12) Mark under the picture that shows this: Each circle in the group fits inside the circle in front of it. [Ans.: ○○○○]

(13) Look at the circle that is divided into parts. Mark under the group of dots that tells the number of parts in one-half the circle.

(14) Mark under the picture that shows this: Two children are swinging. The smaller child is swinging higher and is leaning back.

(15) Look at the people in the first box. Now look at the space suits in the second box. There is one space suit that just fits each person. Mark under the space suit that just fits the person marked with an X.

(16) Mark under the picture that shows a fork above the plate and a spoon beside the plate.

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(17) Look at the shapes in the squares at the beginning of the row. Listen to what happens. Each shape moves to the corner square closest to it. In the last part of the row, mark under the picture that shows how the shapes look now.

(19) Mark under the picture that shows this: Every shape in the group is just like the one in front of it, but is turned upside down. [Ans. ⌊⌐⌊⌐]

(20) The box at the beginning of the row shows a pie that Mrs. Spencer baked. Four children each had one piece. In the past part of the row, mark under the picture that shows how many pieces were left.

(21) Look at the letters in the box at the beginning of the row. They are X, O, C. In a secret code, X stands for O, and O stands for C. In the last part of the row, mark under the letters that stand for O, C.

(23) The box at the beginning of the row shows two plates of cookies. In the last part of the row, mark under the number that tells how many cookies should be moved from the top plate to the bottom plate so that both plates have the same number of cookies on them. [3 cookies on top plate, 1 on bottom]

(24) Mark under the picture that has an X in the center and a star in the outer ring.

(25) Mark under the key that is between two keys whose ends point up.

(27) Mark under the box where all the letters in the top row are the same as the letters in the bottom row of another box. [Each box contains 3 rows of 3 letters each]

(28) Mark under the pair of lines that do <u>not</u> go in the same direction. [non-parallel]

(29) A piece of bubble gum costs two cents and Brian has ten cents to spend. If he spends all his money on bubble gum, mark under the picture that shows how many pieces he can buy.

(30) Four children are playing with toy airplanes. The oldest child has the smallest plane, the next-to-oldest child has the next-to-smallest plane, and the youngest child has the largest plane. Mark under the plane that the next-to-youngest child has.

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Appendix B

Series Completion Test

1. Alternation of two dissimilar objects (candy canes and hearts).

2. Alternation of one horizontal and two vertical lines.

4. Sequences of three letters--response requires first letter of third set.

5. Sequences of three geometric shapes--response requires second item of third set.

7. One sequence of rectangles of decreasing size--response requires third in a set of five.

8. Sequences of three letters--response requires third letter in second set.

9. Sequences of four shapes consisting of white triangle, red triangle, white square, red square. Response requires fourth item from second set.

10. Alternation of two objects dissimilar (plate and glass)--response requires next two steps in sequence.

11. Sequence of four dissimilar objects (bottle, glass, cup, plate)--response requires fourth item of second set.

12. Sequence of four dissimilar geometric shapes--response requires fourth item of second set.

13. Sequence consisting of pairs of similar letter-like shapes--shape 1, shape 1 inverted, shape 2, shape 2 inverted, shape 1--response is then shape 1 inverted.

15. Sequence of three punctuation marks--response requires second item of second set when third item is present.

18. Sequence with three different sets of letter-like shapes--shape 1, shape 1 reversed, shape 1; shape 2, shape 2 reversed, shape 2. Response requires third item of set with shape 3.

19. Alternation of set of three similar configurations--two small circles with lines both over and under, circles with line over, circles with line under. Response requires second item of third set.

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